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Dear Joshua:

I feel bad that I have not responded sooner to your "serious speculation" note of October 21. It deserves a serious reply, and time for quiet thought has been a bit sparce for me lately.

I think the answer to your question about fissile-ability of graphitic embryos may well be yes, but only if they are highly excited by a collision with some energetic particle. If embryos of the spiralling sort we suggested exist in abundance in space, they will have an open graphitic edge on the surface. I would expect the result of a slow heating of such an object would simply be the evaporation of small carbon radicals off this edge. This is what graphite does, and I see no reason to think that the tiny spiral embryo would behave any differently. The dominant fragment would probably be C_3 since it is highly stable and can easily be removed from the open edge with a minimum of reorganization. The alternative process where the open edge lifts off the particle, curls around and forms C_{60} while it cuts itself off from the remaining particle would have a much higher barrier due to all the bond rearrangement and breaking that has to be done before the fullerene cage begins to close.

But if there is some process that can put a lot of energy into the particle on a short (sub-millisecond) timescale, I'm fairly sure much bigger pieces would be blown off. We see this quite clearly in the fragmentation behavior of the fullerenes themselves. With just enough excitation to get the fragmenation process started at a fast enough rate to compete with cooling by infrared emission (for C_{60} this is expected to be about 30 eV) we know the only significant fragmention channel is the "shrink-wrapping" mechanism which involves the concerted loss of C_2 while the next smaller fullerene is formed. But when we dump in more energy in a single 5 nsec laser pulse (through largely incoherent sequential multiphoton absorptions) we see loss of much larger carbon fragments from the cage. The evidence for this is a bit indirect, but it is quite firm. Bob Curl and I worked this out in our first C_{60} photophysics paper in 1987 -- I've enclosed a copy. We show there a mechanism where C_4 or C_6, or larger linear carbon chains can be lost from the fullerene cage in a concerted manner. Whether this mechanism or some other is responsible we do not know, but the experiments show that large C_n fragment losses must become the dominant process at high levels of excitation.

We have so far not been able to probe the fragmentation behavior of the spiral embryos --- our cluster beam and analysis techniques currently run out steam at about C_{600} which is still too small to see any evidence of open structures. Up to this size all the clusters we have probed have simply turned out to be giant fullerenes. But my guess is that we'll ultimately find the

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spiral embryos also loose large carbon chain fragments when they are pulse-heated. Certainly small radical evaporation will be fast from the open edge, but most of the surface of these embryos is a continuous graphite sheet with a few pentagons thrown in here and there. At high levels of excitation won't this surface begin to fragment like a highly-excited fullerene? This provides a source for large linear carbon chains in the ISM. As they aggregate (which I'm sure they'll do quite nicely without the aid of a 3-body collision) they might easily become big enough to serve as a nucleus for condensation of atoms and small molecules in the ISM.

I wonder, though, if the flux of sufficiently energetic particles is high enough under the relevant astrophysical conditions to make such fission-fragmentation of graphitic grains (whether spiral or not) a significant process. Photons just won't do it unless their flux is similar to our pulsed lasers. What do you think?

With best wishes,

R. E. Smalley

P. S. Thanks for the fine help with the bibliography. I took your advice and dropped the old rumor about the burning library in Alexandria. I've enclosed the most recent version. Enjoy!

enclosures: JCP C60 photophysics paper.
Giant Fullerene Thermionic emission paper
Buckybib